WAVELENGTH STABILIZATION MODULE HAVING LIGHT-RECEIVING ELEMENT ARRAY AND METHOD OF MANUFACTURING THE SAME

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

The present invention relates to a wavelength stabilization apparatus in a WDM or analog optical communication system, and more particularly, to a wavelength stabilization module having a light-receiving element array which has the dependency of incident angle of a transmission light passing through a F-P filter, to stabilize the wavelength of light output from a laser diode, and a method of manufacturing the same.

DESCRIPTION OF THE PRIOR ART

In Wavelength Division Multiplexing (WDM) light source module, a multi-functional device has been a world's trend, and the wavelength stabilization function becomes more important in the channel interval of 100GHz or less. According to this trend, the transceiver module for stabilizing the wavelength becomes one of the most important components in point of view that the structure of the system is simplified so as to increase an economical efficiency and reliability.

Conventionally, to stabilize the wavelength of the transmitted laser beam, various methods such as using a reference absorption gas, a grating, a

fiber grating, or a Fabry-Perot (F-P) filter have been used. Among them, efficient and economical means capable of receiving a wide wavelength range in dense WDM (DWDM) having at least several tens of channels is obtained using the F-P filter. The wavelength control precision of wavelength stabilization module developed until recently is approximately 20-50pm. With this numerical value of the wavelength control precision, the wavelength stabilization module is applicable to the WDM system having channel interval of 100GHz. However, since most of the modules are external type modules, they have problems in that the systems thereof are complex.

The wavelength stabilization system using the F-P filter has been mainly used in stabilizing the wavelength of a Distributed Feed-Back (DFB) laser diode. As a tuning method for locking the wavelength of the laser diode to the wavelength of an International Telecommunication Union-Telecommunication (ITU-T) grid, several ways have been developed such as the tilting of the angle of an etalon filter, the change of the cavity's length according to the temperature change of the etalon filter, or the change of the mechanical cavity's length according to piezoelectric actuation.

In general, the wavelength of the DFB laser diode is varied by the second method using the temperature change of the wavelength stabilization module including the etalon filter on a Thermo-Electric Cooler (TEC). The degree of wavelength variation is approximately 0.1nm/°C, and temperature for stabilizing the wavelength is about 10°C in 100GHz-FSR (Free Spectral Range) system. However, when the wavelength tuning function due to the temperature's change is performed in the wavelength stabilization system, the

operation condition of the laser diode may be affected, and thus the driving condition of the element becomes very restricted.

In addition, the method of stabilizing the wavelength by tilting the angle of the etalon filter has very high sensitivity in the fine-tilting of the angle. Theoretically, if the wavelength stabilization module is tilted by about 0.01° in an initial state with a rotation of 8° to decrease the reflectivity noise, the wavelength change of about 0.05nm can be obtained. However, it is difficult for the wavelength stabilization system to be aligned with an accuracy like that, in practical realization, and the yield thereof may be low and the cost thereof is very high.

SUMMARY OF THE INVENTION

Thus, the object of the present invention is to provide a wavelength stabilization module having a light-receiving element array and a method of manufacturing the same which can decrease the reflection noise and can stabilize the wavelength by tilting a filter and a photodiode, while uniformly maintaining the temperature of the system.

In order to accomplish the above-mentioned object of the present invention, a wavelength stabilization module having a laser diode which irradiates a laser beam at the front side and the rear side thereof comprises a collimator for paralleling the laser beam irradiated at the rear side; a beam splitter for splitting the laser beam passed through the collimator into the two directional laser beams; a light-receiving element for receiving one of the split laser beams; a filter for transmitting a specific wavelength of the other of the

split laser beams; a light-receiving element array for receiving the laser beam passed through the filter; and a controller for controlling the output wavelength of the laser diode by using the signals output from the light-receiving element and the light-receiving element array, and the filter and the light-receiving element array are tilted at a predetermined angle with respect to the laser beam and lock the wavelength by using an incident angle dependency of the laser beam passed through the filter.

In order to accomplish the above-mentioned object of the present invention, a method of manufacturing the wavelength stabilization module comprises the steps of assembling the laser diode, the collimator, the beam splitter, and the light-receiving element on a TEC; mounting the TEC on a butterfly package; applying an input signal to the laser diode to operate the laser diode; and mounting a sub-mount mounted with the filter and the light-receiving element array at a predetermined angle and a predetermined distance, while monitoring the wavelength of the beam of the laser diode, under controlling the temperature by the TEC.

The present invention relates to a wavelength detection and stabilization apparatus used in a WDM optical communication system or an analog optical communication system, and provides a new module structure and package for stabilizing the wavelength of a multi-channel wavelength variation light source device. In the structure of the wavelength stabilization apparatus, the conventional problems can be overcome by arranging a plurality of light-receiving elements at an appropriate location in a light-receiving section for receiving the light passed through the filter and by using

the dependency of incident angle between the light receiving elements. This light-receiving element may be a photodiode, and the filter is preferably an F-P (Fabry-Perot filter).

In the module having the beam splitter, the collimator for collimating a beam, the F-P filter, the monitor photodiode, and the photodiode array at the rear side thereof, the wavelength stabilization function can be implemented in the whole wavelength range by a method of aligning the angles of the F-P filter and the photodiode array block. In case of using the photodiode array, a method of combining and using the outputs of a plurality of photodiodes or one photodiode among a plurality of the photodiodes is used to lock the laser beam with a target frequency. Particularly, F-P filter and a photodiode array are fixed on a sub-mount to be blocked, the wavelength stabilization function satisfying the wavelength interval of the multi-channel WDM communication standard can be provided by using the dependency of incident angle of the transmission light passed through the F-P filter and the photodiode in the photodiode array.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 illustrates the package structure of a wavelength stabilization module having a light-receiving element array according to a preferred embodiment of the present invention.

Fig. 2 shows the chang of the FSR when a F-P filter having a 50GHz FSR is tilted by a certain angle.

Fig. 3 illustrates the progressed path of the laser beam when the F-P

filter is tilted by 8°.

Figs. 4a and 4b show the fine chang of a wavelength due to the fine error of the wavelength when the F-P filter having 50GHz FSR is tilted by 8°.

Fig. 5 illustrates the operation of the wavelength stabilization module having the light-receiving element array according to the preferred embodiment of the present invention.

Fig. 6 shows the spread degree of the laser beam passed through a collimator.

Fig. 7 illustrates the fine change of an incident angle when the F-P filter and the photodiode array are positioned in the paralleled path of the laser beam.

DESCRIPTION OF PREPERRED EMBODIMENTS

Hereinafter, embodiments of the present invention will be explained with reference to the accompanying drawings. However, the embodiment of the present invention can be changed into a various type, and it should be not understood that the scope of the present invention is limitted to the following embodiments. The embodiments of the present invention are provided to explain the present invention to those skilled in the art.

Fig. 1 illustrates the package structure of a wavelength stabilization module having a light-receiving element array according to a preferred embodiment of the present invention. In a butterfly package **132** having 14 pins, a laser diode (LD) **100** is mounted on a sub-mount **102**, and the front side of the laser diode **100** is connected with an external optical fiber through a

coupler **108** to transmit the laser beam to the external optical fiber. Also, the laser diode **100** irradiates the beam at the rear side thereof to perform a wavelength stabilization function. The laser beam irradiated at the rear side of the laser diode passes through a collimator **110** so that the laser beam can be transferred to a long distance. The beam passing through the collimator **110** is split into two directional beams by a beam splitter **112**. One of the two split beams is transmitted to a photodiode **116** so that the power of the whole laser beam is monitored, and the other of two split beams is transmitted to a F-P filter **122** and a photodiode array **126** so that the wavelength of the laser beam is monitored. The F-P filter **122** functions as a resonator and allows the beam having a wavelength of a certain range to pass and allows the other not to pass.

The components such as the laser diode **100**, the collimator **110**, the coupler **108**, and the beam splitter **112** are positioned on a TEC **104** to maintain the operation temperature of the element to be constant. In order to allow the TEC **104** to maintain the predetermined temperature, the TEC **104** is operated with a thermistor **106**. In order to reduce the reflection loss of the laser beam, the F-P filter **122** and the photodiode array **126** are tilted by a certain angle with respect to the propagation direction of the laser beam. Here, the more the angle is increased, the more it is difficult to implement them, and preferably, the tilting angle is in the range of 2° to 10°. Alternatively, if an isolator is used to reduce the reflection loss of the laser beam, the F-P filter **122** and the photodiode array **126** may be not tilted by the certain angle with respect to the propagation direction of the laser beam.

While tilting, the tilting angle is preferably 8°, and a sub-mount **102** for the laser diode and a sub-mount **120** for the F-P filter and the photodiode array are used so as to easily perform the tilting operation. Also, a monitor photodiode **116** is may be mounted on the sub-mount **114**. The mounted-module is finally connected to each of pad portions on the butterfly package **132** through wires **130**.

The wavelength stabilization module according to the present invention can be manufactured by independently modularizing each sub-mount and then mounting the total modules. Alternatively, the wavelength stabilization module according to the present invention can be manufactured by mounting the components such as the laser diode **100**, the collimator **110**, the coupler **108**, the beam splitter **112**, and the photodiode array **126** on the total modules, respectively. In the former, a silicon substrate manufactured by a micro-machining process is used as the sub-mount. At this time, in order to easily mount each of the components on the silicon sub-mount, a pattern may be formed or a trench may be formed according to the size of the each component, and thereby the arrangement and the assembly thereof can be manually performed.

The approximate sequence of the total module assemble is as follows: First, the sub-mount **102** for the laser diode on which each of the components including the laser diode **100** is assembled is mounted on the TEC **104** and then the TEC **104** is mounted in the butterfly package **132**. Then, an input signal is applied to the laser diode **100** to allow the laser diode to be operable. And, the photodiode array block is mounted and arranged, while monitoring

the wavelength of the beam output from the rear side thereof under controlling an appropriate temperature. At this time, the photodiode array block is fixed at a desired location, with a certain angle and a certain arrangement distance. When the photodiode array block is mounted, it may be fixed by means of adhesive material such as epoxy, solder, laser welding, or the like.

Fig. 2 is a graph showing the degree of a FSR variation when the F-P filter having 50GHz-FSR is tilted by a certain angle. Generally, the F-P filter **122** is manufactured under a condition that the beam is incident in perpendicular to the filter. However, if the F-P filter **122** is tilted to reduce the reflection loss, the FSR value is non-linearly changed according to the tilting angle so that an initial FSR value is changed into a different value. Accordingly, in case the initial tilting angle of F-P filter **122** is set to be 8° as illustrated in one embodiment of the present invention, the desired FSR value needs to be calculated at the time of manufacturing the F-P filter **122**. If the F-P filter **122** having 50GHz-FSR is desired to be manufactured when tilted by 8°, the F-P filter 122 having 49.51-49.52 GHz FSR must be manufactured under the condition that the beam is perpendicularly incident.

Fig. 3 illustrates the propagation path of the laser beam when the F-P filter is tilted by 8°. The laser diode **100**, the collimator **110**, and the F-P filter **122** are shown, and the tilting angle was set to be 8° so that the laser beam reflected from the F-P filter **122** reaches the laser diode **100** so as not to generate noises. At this time, the distance between the collimator **110** and the F-P filter **122** is about 3.6mm. As shown in Fig. 1, according to the simulating results to the propagation path of the beam, it is preferable that the

tilting angle is 4° or larger than 4°. However, the tilting angle may be changed in accordance with the distance between the collimator **100** and the F-P filter **122**, the parallel degree of the beam of the collimator **110** or the like.

Figs. 4A and 4B are graphs showing the change of transmittance in wavelength depending on the fine error of F-P filter's tilting. The tilting angle of the F-P filter is adjusted with 8°. Fig. 4A shows the cases that the errors are generated with the intervals of 0.1° at the initial set angle 8°, and Fig. 4B shows the cases that the errors are generated at the intervals of 0.01°. Referring to Fig. 4A, the peak of transmittance in the wavelength was hardly shifted, and, referring to Fig. 4B, the peak of transmittance in the wavelength was shifted by about 0.05nm. Based on these, the wavelength shifting effect is dominant by tilting the F-P filter **122** at the intervals of 0.01°. That is to say, in case the tilting angle is increased from 8° by 0.01°, the peak of transmittance in the wavelength was shifted toward the short wavelength as shown in Fig. 4B. In case the tilting angle is decreased from 8° by 0.01°, the peak of transmittance in the wavelength was shifted toward the long wavelength by the same interval. This effect can be generated only when the initial tilting angle is 8°. In case the errors are generated with the intervals of 0.1° at the initial set angle 8°, the peak of transmittance is positioned at the location similar to the location of the original wavelength, and thereby the error in the arrangement of the tilted location is low to some extent.

Fig. 5 illustrates the operation of the wavelength stabilization module having the light-receiving element array according to the preferred embodiment of the present invention. The laser diode **100**, the collimator

110, the beam splitter **112**, the F-P filter **122**, and the photodiode **126** are positioned on the TEC **104**. In order to drive the laser diode **100** at a constant temperature, the temperature is detected by the thermistor **106**, and is always maintained uniform by a TEC driver **504**. The laser beam output from the rear side of the laser diode **100** is paralleled by the collimator **110**, and then split into the two directional beams by the beam splitter **112**. Generally, the beam is split at the ratio of 50:50, but preferably it is split at the ratio of 70:30 in consideration of the strength of the signal. Practically, 30% of the laser beam is directed to the monitor photodiode **106**, and 70% thereof passes through the F-P filter **122** to be directed to the photodiode array **126**. But, since the loss of about 10% or less is generated in the F-P filter **122**, the beam from the photodiode array **126** becomes about 60%. Accordingly, the output of the monitor photodiode **106** becomes a half of the output of the photodiode array **126**, and the variable resistance for adjusting the diode's reception sensitivity can be smaller.

A controller **500** monitors the output of the monitor photodiode **106** and the output of the photodiode array **126** and a control signal from the controller **500** is fed back to the input terminal of a laser diode driver **502** to stabilize the output wavelength of the laser diode **100**. The controller **500** can be implemented with an operational amplifier, and function as converting the wavelength of the laser diode by calculating the input current due to the error of the output wavelength of the laser diode and inputting it to the laser diode driver.

Fig. 6 is a graph showing the spread degree of the laser beam passing

through a collimator. According to the preferred embodiment of the present invention, the distance between the collimator **110** and the F-P filter **122** is 3.6mm. In this case, it is noticed that the beam at the surface of the F-P filter **122** is spread by about 13.16μm. Accordingly, if 13.16μm is split by 3.6mm, it is noticed that the spread degree of the beam (θ) is about 0.2°. This result is dependent on the collimator **110,** or arranged degree of the focus distance from the collimator **110.**

Fig. 7 illustrates the fine change of an incident angle when the F-P filter and the photodiode array are positioned in the parallel path of the laser beam. The laser beam irradiated from the rear side of the laser diode passes through the collimator **110** and the F-P filter **122** to reach the photodiode array **126**, and the laser beams received at each photodiode have different angles from each other. In case of using the photodiode array **126,** the wavelength variation between the photodiodes can be expected to have about 0.1nm, as shown in Fig. 7. According to the preferred embodiment of the present invention, it is preferable that all of 4 photodiodes have sizes of 50μm×200μm and their intervals are 20μm, 60μm, and 20μm, respectively as the wavelength variation interval between the photodiodes becomes about 0.1nm due to the angle dependency. One of the 4 photodiodes in the photodiode array block can be located in a desired wavelength, though some error is generated when the photodiode array block is arranged. Accordingly, by using the method suggested in the present invention, the difficulty of wavelength stabilization while tilting the photodiode array lock at the interval of 0.01° can be overcame. Practically, though some arrangement error is generated, one photodiode in the

photodiode array 126 can be positioned at a desired location to cover the total wavelength band.

According to the present invention, the wavelength stabilization module for a multi-channel variable wavelength light source, which can be used in a WDM application having a dense wavelength interval, can be manufactured. It is accomplished through the fine wavelength variation effect due to the fine change of the incident angle of the transmission light passing through the filter by using the photodiode array and the filter tilted by the certain angle with respect to the direction of the laser beam. In addition, the wavelength of the laser beam can be locked to a desired wavelength channel at a certain temperature by using the TEC, without changing the operation temperature of the laser diode, and low cost and high yield can be accomplished.

Although the present invention has been illustrated and described with respect to exemplary embodiments thereof, the present invention should not be understood as limited to a specific embodiment, and it should be understood by those skilled in the art that the foregoing and various other changes, omission and additions may be made therein and thereto, without departing from the spirit and scope of the present invention.